The Technology Matrix: A Recommended Approach to Baseline Development under a Market-Based Greenhouse Gas Reduction Regime

National Energy Technology Laboratory (NETL)

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Introduction

Concern for increasing atmospheric concentrations of carbon dioxide and other greenhouse gases (GHG), and the potential impact of these increases on Earth's climate, has led to a series of international meetings and negotiations aimed at reducing global GHG emissions. Moreover, a number of treaties, agreements and voluntary programs have been proposed to address this issue. Whereas earlier activities aimed at controlling emissions of harmful substances centered on command-and-control regulations, the more recent proposals have focused on flexible, market-based procedures that facilitate the use of low cost-solutions for emission reductions. Proposed market mechanisms include emissions trading and a new concept where project developers can obtain credits for investing in project-based GHG emission reduction activities. Although the procedures and framework for responding to the issue of global climate change are still evolving, it is likely that any future domestic or international GHG reduction efforts will rely heavily on such market-based procedures.

The successful implementation and use of project-based market mechanisms will require the development of transparent, cost-effective, and environmentally sound protocols for quantifying the emission reductions associated with different types of projects. Investors will need to be assured of the credibility of the estimated emission reductions before investing in either projects or the tradable credits these projects would yield. Moreover, credible and verifiable data will be required for quantifying the emission benefits of project-specific GHG reduction activities. The National Energy Technology Laboratory (NETL) has been examining the many issues surrounding the transfer of clean technologies and the implementation of market-based mechanisms for controlling GHGs. Recently, NETL produced three reports concerning the development of these market-based mechanisms and analyzed the efficacy of major emission reduction estimation approaches in the marketplace. The first report, *Developing Emission Baselines for Market-Based Mechanisms: A Case Study Approach*, examines three major emission baseline approaches - the project-specific approach, the benchmark approach, and the modified technology matrix approach. To conclude this report, NETL recommended the modified technology matrix for further development, which led to the second report, *Developing the Technology Matrix for India and Ukraine*. The third report, *Case Study Analysis of the U.S. and EU Market Mechanism Proposals*, offers a comparison of the modified technology matrix to U.S. and EU market mechanism proposals released in September 2000. In the following we will summarize the findings of these three reports.

What Is an Emissions Baseline?

An emission baseline represents the standard from which a measure of valid GHG emission reductions or carbon sequestration is established. The baseline can either be derived from a forecast of emissions of the actual activity to be replaced, or on a specific set of emission data collected from relevant sectors within the economy. Once the baseline has been constructed, the emissions associated with the proposed emission reduction project are calculated and subtracted from the baseline to determine the actual emission reductions of the project. The development of emission baselines that are accurate and incur low transaction costs is crucial to enhance participation in market mechanisms and at the same time, ensure that any emissions credits awarded have a positive environmental impact. To date, four general requirements have been proposed to promote the development of emissions baseline approaches. The first refers to the issue of screening out free rider projects; that is, the question of whether a project will receive credit even though it would already have been implemented in the absence of a GHG crediting program. The second requirement stems from the need to ensure accuracy in estimating the emission baseline in order to promote credibility; i.e. the goal becomes to reduce the level of error associated with the baseline rules. As a third requirement, baseline development approaches should provide a transparent (i.e. standardized, clearly defined, and easily replicable) methodology for estimating baselines to facilitate increased participation and ensure the credibility of the emission reductions. Finally, an effective baseline development methodology should minimize transaction costs to encourage the inclusion of a maximum number of projects.

Free Ridership

A major requirement contained within the market mechanism concept is the need to ensure additionality of the projects that receive credits. This issue refers to whether an emission reduction project will produce emission benefits in addition to those that would have occurred without the project. Activities and projects that help reduce emissions are likely to occur in the absence of an international GHG emission reduction agreement or market mechanism incentives because of competition, technological advancements, or other unforeseen factors that encourage firms to reduce their carbon intensity. These projects or activities are often referred to as business-as-usual projects, and it is these projects/activities that the additionality requirement is intended to screen out from receiving reduction credits. Business-as-usual projects that somehow manage to pass the additional screen and receive credit are known as free riders. In this context, testing for free rider projects becomes the de facto test for determining whether a project qualifies for reduction credits and distinguishing additional projects from non-additional projects. This requirement is necessary to maintain the environmental integrity of any GHG crediting program.

Level of Error

Accuracy in the estimation of the emissions baseline ensures the credibility of emissions credits. Hence, any standardized baseline procedure must strive to minimize the level of error associated with awarding and estimating credits. Two issues in particular have an impact on the level of error; 1) the treatment of additionality as a criterion for project certification and 2) the consideration of temporal issues in the development and quantification of baselines will determine whether accuracy of the emission credits generated throughout the life of the project is maintained over time.

The first issue deals with the mis-classification of additional and non-additional projects. Errors in the classification of projects according to their additionality status will lead directly to systematic errors in project emission reduction estimates. If a non-additional project is mis-classified and qualifies as additional, it will be undertaken and awarded credits resulting in an overestimation of emission reductions. However, if an additional project is mis-classified as non-additional, it will not be undertaken, because by definition an additional project will not be implemented absent the awarding of emission credits, ultimately driving up the cost of emission reductions. In addition, misclassified non-additional projects as additional will lead project developers to preferentially invest in these non-additional projects at the expense of the truly additional projects because non-additional projects tend to be more economically attractive than additional projects. Moreover, additionality classification errors always lead to emission reduction estimation errors equal to 100 percent of the estimated project emission reductions. To protect against potential classification errors a rigorous additionality test is necessary and may ultimately prove to be both cost effective and the best means of guarding against large systematic bias in project emission reduction estimates.

The second issue affecting the level of error is the treatment of time. Failure to accurately predict the future emissions path of a project's reference scenario will lead to error in the baseline against which the potential project is compared and the awarded credits will not reflect the true environmental impact of the project. As a result, flexible procedures that take into account changes occurring over time should be incorporated into the baseline methodology.

Transparency

Early experiences with emission baselines and co-operative abatement activities demonstrated that the lack of clearly defined assumptions and guidelines regarding methods for quantifying baselines was a major problem. The lack of standardized information requirements hindered project replication, complicated independent verification of projected emission benefits, and overstated projected emission reductions. To minimize the use of subjective and untestable baseline assumptions, common and explicitly defined methodologies for estimating baselines are needed. The introduction of more clearly defined guidelines would promote increased understanding and prevent complicated and time-consuming approval processes that may delay a potential project to the point where it is no longer economical. Moreover, improved transparency would facilitate replication of projects thereby encouraging participation. Objectivity would also be fostered and opportunities for political manipulation would be reduced, increasing the credibility of the emission credits generated.

Transaction Costs

The transaction costs associated with project and baseline development will have a considerable impact on the number of projects, particularly smaller sized, that will apply for emission credits. Early experience with baseline development on a project by project basis have shown transaction costs associated with project development to be very high and cost prohibitive. To ensure participation by all types and sizes of projects the use of standardized approaches to baseline development are necessary. Standardized approaches reduce the amount of time that individual project developers spend on developing and quantifying their emission baseline. In particular, such approaches will reduce the amount of time spent on demonstrating additionality for individual projects. Furthermore, a standardized baseline methodology will be easier to verify and replicate.

Baseline Methodologies

Considering these four criteria, there are trade-offs between the objectives of ensuring additionality, low level of error, transparency, and reduced transaction costs. To increase transparency and reduce transaction costs a certain level of standardization in the application of the baseline approach is required. However, as baselines become more standardized, the level of error in estimating credits increases. In addition, the inclusion of a rigorous free rider test is likely to increase the transaction costs involved in baseline development. To offset some of these costs, various standardized approaches to baseline development have been proposed. Two major baseline approaches, the project-specific approach and the benchmarking approach, represent opposite ends of the spectrum in terms of trade-offs between these criteria.

The project-specific approach: This approach involves the tailoring of a separate baseline estimation methodology to each individual project, based on a detailed analysis of the project's defining characteristics. A project's free rider status is assessed through an evaluation of its economic feasibility and an examination of possible non-financial barriers to project implementation such as poorly functioning capital markets, risks associated with operating locally unknown technology, and institutional barriers or structures that discourage investments in energy sector improvements. In short, free rider projects are determined under this approach by this question: would the project have been implemented in the absence of market-based mechanism incentives (i.e. emission credits). If the answer is yes, then the project is a free rider and would not qualify. Of course the opposite is true if the answer is no. A separate baseline for each project would then be developed to calculate the project's emission reductions based on what would have occurred in the absence of the project activity. In other words, what is the business as usual scenario? The project-specific approach is potentially the most accurate method of setting baselines. However, its accuracy comes at the expense of high transaction costs and lack of transparency.

The benchmarking approach: This approach relies on an average, median, or other metric derived from a defined aggregate or category (such as a specific region, sector, or technology) to determine the amount of emissions reduced by a given project. Based on the performance of this aggregate, a benchmark is then developed, which projects must improve upon to generate emission reduction credits. Benchmarks may be aggregated at a national, sector, sub-sector, or global/regional level. Eliminating the use of a site-specific, case-by-case estimation of emissions with and without the project increases transparency and reduces transaction costs. However, the benchmarking approach does not address the issue of free ridership separately from the construction of the emission baseline, offering no test for free rider projects. Thus, the level of error increases under this approach, but it is highly transparent and substantially reduced transaction costs.

A technology-based alternative: Over the last two years, the National Energy Technology Laboratory (NETL) developed a third alternative approach to developing standardized emission baselines called the modified technology matrix. This approach represents the middle ground between the objectives of ensuring accuracy and transparency and mitigating transaction costs by introducing a high level of standardization coupled with a rigorous free rider test. In NETL's view, the modified technology matrix represents the best opportunity for project developers to satisfy the above requirements and objectives.

Early Version of the Technology Matrix

The concept of the technology matrix was originally created as an extension of the benchmarking approach whereby credible emission reductions of a project are determined through a comparison with a selected group of technologies.[1] Following this approach, the average emissions performance of a number of pre-defined default technologies, which have already reached a predetermined market threshold, would be selected to represent the benchmark for a specific time and within a defined region. In short, a project would be compared to a predetermined matrix of technologies that are readily available locally at the time. Technologies that reduce emissions below the baseline would automatically receive credit for the amount of emissions reduced. The technology benchmark would be reevaluated regularly and as new technologies reach the market threshold they would be added to the list of technologies on which the benchmark is based. The benchmarks could be differentiated to fit specific technologies, sectors, and project types. In sum, this version of the technology matrix is a benchmark derived from current and widely implemented technologies.

Because this early version of the technology matrix is similar to a benchmarking approach, it shares similar baseline development problems, in particular issues involving accuracy and free ridership. Like the benchmarking approach, it fails to adequately eliminate free rider projects. As noted, a project's emission rate would be compared with a pre-selected technology benchmark. If a project's emission rate is higher than the benchmark the project is deemed a free rider; if it is lower, a project qualifies as additional. This numeric comparison of two emission rates does not address the key question that determines additionality, i.e. is the project viable absent market-mechanism incentives? Like the benchmarking approach, this simple numeric comparison would likely result in the misclassification of a large number of free rider projects as additional (and vice versa). In addition, project developers seeking emission reduction credits would preferentially invest in the misclassified free rider projects at the expense of

[1] Tim Hargrave, Ned Helme and Ingo Puhl, "Options for Simplifying Baseline Setting for Joint Implementation and Clean Development Mechanism Projects," JI Braintrust Group: Minutes of the February 18-19, 1998 Meeting, Center for Clean Air Policy and JI Braintrust Group: Minutes of the May 4-5, 1998 Meeting, Center for Clean Air Policy. November 1998.

additional projects. This follows from the fact that by definition the latter projects will tend to be less viable then the former. Furthermore, this early version of the technology matrix raised questions as to which baseline technologies should be included in the development of the benchmark.

The Modified Technology Matrix

The modified technology matrix was developed by NETL to address the concerns of the original technology matrix concept. The modified technology matrix represents a more cost-effective, transparent, and reasonably accurate approach to quantifying greenhouse gas emission reduction project baselines. It is similar to other benchmarking approaches but with the addition of an effective, rigorous test to eliminate free rider projects. It also addresses the problem of which technologies to include in the benchmark/baseline. The modified version consists of a selected list of pre-approved, greenhouse gas emission reduction technologies. These technologies qualify for the list by passing rigorous tests of the candidate technology's economic feasibility and market penetration in the host country. These tests are a means of weeding out business-as-usual or free rider projects. In general, only advanced, non-commercial technologies are likely to pass the test and qualify for inclusion in the matrix.

Economic Feasibility Test: This test involves the determination of a candidate technology's commercial viability through comparing the specific candidate technology's costs to the costs of alternative commercial technologies in a selected country. In addition to accounting for the cost of implementing the technology itself, factors to be considered in determining a candidate technology's economic feasibility should include energy costs, environmental regulation, tariff structures, etc. Other considerations to be taken into account include whether construction costs can be predicted with reasonable certainty and whether the operational performance of the technology can be guaranteed. If the technology proves unable to compete with current market technologies – in other words the technology is not commercially viable – it would pass this test and qualify for inclusion in the matrix. Technologies that are likely to pass the economic feasibility test include renewable technologies such as solar and wind, integrated gasification combined cycle technologies, and integrated gasification fuel cell technologies.

Market Penetration Test: In select countries, some technologies may prove to be commercially viable but still face certain non-financial barriers to implementation. These barriers could include risks associated with installing and operating locally unknown technologies, institutional barriers or internal organizational structures that discourage investment in energy sector improvements, or poorly functioning capital markets that prevent new technologies from being adopted. If a commercial technology were shown to have a weak market penetration rate in a certain country, then the technology could still qualify for inclusion in the matrix.

Ideally, the economic feasibility and market penetration tests should work together to qualify technologies for inclusion in the matrix. However, in some instances only one of the tests may be sufficient to qualify a particular technology.

Establishing the Baseline Under the Modified Technology Matrix[2]

Once a technology qualifies, a benchmark is developed for that specific technology based on the emissions performance of a counterfactual technology(ies). The counterfactual represents the technology most likely to be utilized if the corresponding advanced-technology project were to be foregone. There are three basic steps to estimating the benchmark. First, the most likely alternative to the project must be defined in a qualitative manner (i.e. what is the counterfactual technology?). Second, the data required to quantify the benchmark must be collected for each technology/country combination. Finally, the collected data is analyzed, and used to compute the benchmark (i.e. the baseline against which the project emissions will be compared). Once the benchmark is established, utilizing the technology matrix is a straightforward process for project developers. To qualify for emission credits, project developers would simply demonstrate that the proposed project technology is included in the matrix. Then, the amount of credits to be awarded to the project would be determined by subtracting the project's emission rate from the stipulated benchmark.

As time passes, the economic performance, technological capabilities, and energy intensity of a nation are likely to change. As a result, the list of pre-qualified technologies should be updated regularly, preferably every five years, to capture the impact these changes may have on the individual technologies. If this periodic review reveals that individual technologies are no longer additional, they should be removed from the matrix and added to the activities that make up the baseline. Similarly, the technology baselines also should be updated every five years to account for the introduction of new technologies and other changes that may influence the composition of the benchmark groups used to establish the baselines. An example from the power generation sector of any given country can be used to illustrate this point. An initial group of existing power plants would be selected as best representing the "typical" counterfactuals for projects using a qualifying technology; the average heat rate or emissions rate for this benchmark group would be applied to the first group of projects qualifying under the technology matrix. However, after five years, a new benchmark group, reflecting changes and/or improvements in power plant technology, would be used as the basis for a new benchmark to be applied to all new projects implemented as of year six. In a similar fashion a new benchmark group of existing power plants would be used to establish a new benchmark at each following five-year interval. Moreover, the baselines developed from the original counterfactual power plants would be updated every five years as well. The development of these plants would be traced over time to account for changes in heat rates and wear and tear on the equipment. In this way, the power plants and technologies originally selected for developing the stipulated baseline will continue to serve as the benchmark throughout the life of the first group of qualifying projects. Table 1 presents a sample technology matrix for several countries/technology combinations, illustrating the element of time in baseline development for the technology matrix.

[2] For simplicity, the modified technology matrix will be referred to as the technology matrix from this point forward.

Table 1. Sample Technology Matrix with Initial and First Two-Year Baseline Updates

Countries		India			China			Argentina		
Qualifying Technologies		**Year 1**	**Year 6**	**Year 11**	**Year 1**	**Year 6**	**Year 11**	**Year 1**	**Year 6**	**Year 11**
Coal-Fired IGCC	**BMG a**	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}
	BMG b	---	B_b	B_{b+5}	---	B_b	B_{b+5}	---	B_b	B_{b+5}
	BMG c	---	---	B_c	---	---	B_c	---	---	B_c
Solid Oxide Fuel Cells	**BMG a**	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}
	BMG b	---	B_b	B_{b+5}	---	B_b	B_{b+5}	---	B_b	B_{b+5}
	BMG c	---	---	B_c	---	---	B_c	---	---	B_c
Phosphoric Acid Fuel Cells	**BMG a**	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}
	BMG b	---			---	B_b	B_{b+5}	---		
	BMG c	---	---		---	---		---	---	
Molten Carbonate Fuel Cells	**BMG a**	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}
	BMG b	---	B_b	B_{b+5}	---	B_b	B_{b+5}	---	B_b	B_{b+5}
	BMG c	---	---	B_c	---	---	B_c	---	---	B_c
Proton Exchange Membrane Fuel Cells	**BMG a**	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}
	BMG b	---	B_b	B_{b+5}	---	B_b	B_{b+5}	---	B_b	B_{b+5}
	BMG c	---	---	B_c	---	---	B_c	---	---	B_c
Photovoltaics	**BMG a**	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}
	BMG b	---	B_b	B_{b+5}	---	B_b	B_{b+5}	---	B_b	B_{b+5}
	BMG c	---	---	B_c	---	---	B_c	---	---	B_c
Pressurized Fluidized Bed Combustion	**BMG a**	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}	B_a	B_{a+5}	B_{a+10}
	BMG b	---	B_b	B_{b+5}	---	B_b	B_{b+5}	---	B_b	B_{b+5}
	BMG c	---	---	B_c	---	---	B_c	---	---	B_c

A Back-Up Methodology

Exclusive reliance on any one baseline methodology could result in lost opportunities; therefore, a flexible approach to baseline development protocols is recommended. If a technology fails to qualify for inclusion in the matrix, the technology matrix is designed to employ the project-specific approach as a back-up methodology. The technology matrix is set up to provide a relatively inexpensive method of qualifying and benchmarking projects that utilize advanced non-commercial technologies. However, the technology matrix, if used exclusively, would automatically *disqualify* all projects that utilize standard commercial technologies. While many such projects are in fact likely to prove to be free riders, there will no doubt be exceptions to this rule. Therefore, a back-up methodology is needed to ensure that the technology matrix would not in and of itself eliminate all commercial technology projects from participation in the market mechanisms. Under the technology matrix approach, project developers would always be afforded the opportunity to use the project-specific approach if they cannot use the technology matrix to qualify their projects.

To ensure appropriate selection between the project-specific and the technology matrix approaches under a flexible protocol concept, several guidelines are proposed. Table 2 summarizes these guidelines, as they would relate to the electricity generation sector. As illustrated in row one of Table 2, the technology matrix should be the default procedure for analyzing all projects involving the installation of new generating capacity utilizing one of the qualifying technologies. (Table 2 identifies three exceptions to this rule.) For all projects involving non-qualifying technologies or conventional technologies, the project-specific approach must be utilized. However, projects involving the retrofitting of advanced, qualifying technologies may utilize the technology matrix to determine free ridership while utilizing the project-specific approach to establish the baseline.

Table 2. Criteria for Selecting an Approach to Baseline Development for the Electricity Sector

Project Type	Corresponding Approach	Exceptions
Projects involving the installation of new capacity, and utilizing advanced qualifying technologies	Modified Technology Matrix	1. Projects to be implemented in host countries without qualifying technology lists/sector benchmarks must use the project-specific approach. 2. Project developers may choose to use the project-specific approach to estimate the baseline if they can demonstrate that the result is more accurate. 3. Projects designed to replace existing capacity rather than meet new demand should use the project-specific approach for baseline development if the capacity to be replaced can be readily identified.
All projects utilizing conventional non-qualifying technology.	Project-specific	1. Projects involving the installation of new capacity to meet new demand should use a sectoral benchmark for baseline estimation, unless the project developers choose to use the project-specific approach and can demonstrate that the result is more accurate.
Projects involving the retrofitting of advanced qualifying technologies to existing facilities, with not resulting changed in capacity.	Modified technology matrix free rider test; project-specific to estimate the baseline.	None

NETL's Case Study Approach to the Technology Matrix

Much of the literature on baseline development has focused exclusively on individual methodologies in the abstract. Different estimation approaches have been compared and contrasted, but few attempts have been made to *apply* these approaches. NETL however, has adopted a hypothetical case study approach as a more practical and effective means of illustrating and applying the technology matrix. By using case studies, based on real-world projects and activities, NETL can demonstrate a working technology matrix rather than merely discussing abstract concepts. By undertaking the process of building the matrix through a larger number of examples, key issues to be addressed during matrix development are highlighted, data requirements are identified, availability of data to meet those requirements is determined, and the quality of the available data is assessed. In addition, the strengths and limitations of the modified technology matrix are brought into sharper focus.

The first two reports, *Developing Emission Baselines for Market-Based Mechanisms: A Case Study Approach* and *Developing the Technology Matrix for India and Ukraine*, use this case study approach to demonstrate technology matrix development for a number of select countries and technologies. The matrixes developed for these reports are not intended to represent the final, definitive technology matrix for any of the technology/country combinations. Rather the goal is to highlight the main issues associated with matrix development through concrete, illustrative examples. In the first report, NETL took an initial step by focusing on only two technologies for two developing countries. The first was an IGCC power project in China. The second was an off-grid, solid oxide fuel cell (SOFC) power project in Argentina. As a follow on to the these two case studies, the second report further developed the technology matrix by examining ten selected technologies for India and Ukraine. The ten technologies considered include five electric power generation technologies, three transportation/transportation fuel technologies, and two other technologies. Table 3 lists these ten technologies.

Table 3. Technologies Examined for India and Ukraine

Power Generation	Transportation	Other
• Supercritical Coal • Integrated Gasification Combined Cycle (IGCC) • Natural Gas Combined Cycle (NGCC) • Fuel Cells • Wind Turbines	• Compressed Natural Gas (CNG) Vehicles • Hybrid (electric-gasoline) Vehicles • Gas-to-Liquids (GTL)	• Coalbed Methane Recovery • Energy-plex Projects

Analysis of the two initial case studies revealed that both technologies, IGCC and SOFC, would qualify for inclusion in China's and Argentina's technology matrix respectively. In addition, country-specific qualitative baselines were developed for each technology. In the case of the Chinese IGCC plant, conventional coal-fired power plants would be used to establish the qualitative baseline while new diesel generators would make up the qualitative baseline for SOFC in Argentina. Table 4 illustrates the results of the case study analysis for the ten technologies in India and Ukraine. This table shows that all the technologies, with the exception of supercritical coal and CNG vehicles in Ukraine, would qualify for inclusion in each country's matrix. In a number of instances, separate qualitative baselines have been developed for different applications of the same technologies. For example, two qualitative baselines are provided for wind turbine technology depending on whether the turbines are to be used for off-grid or on-grid applications. Furthermore, in a few cases, qualitative baselines are not developed for a particular technology/application. For example, in the case of solid oxide fuel cells in distributed generation applications, the project-specific approach should be employed to compute emission reductions rather than the technology matrix approach. The energy-plex concept is also excluded from the matrix because this technology had not reached a level of maturation sufficient to warrant its inclusion at this point. Also, a baseline is not provided for estimating the methane emission reductions resulting from coalbed methane recovery projects, because it is not required: the methane reduction can be measured directly for such projects.

Although utilizing available data and information, the basic approach to qualitative baseline development relies primarily on expert judgment. Hence the qualitative baselines established through this process are inherently subjective in nature. This subjectivity is in part a reflection of the hypothetical nature of the qualitative baseline question, what if the emission reduction project was not undertaken, what would happen in its place? In the final analysis, this is a question about an alternative future and one that will not occur (assuming the project is implemented). There is a correct answer to the question – something would happen in the absence of the project – but this something is unknowable. Given these inherent difficulties, a subjective approach of an educated guess based on informed opinion and expert judgment is adopted for each individual technology and country. This subjective approach attempts to reflect and capture the unique characteristics of each technology/country combination in the proposed qualitative baselines. They are by no means offered as definitive and final and are subject to discussion and debate.

Table 4. Technology Matrix Case Study Results for India and Ukraine

Technology	Technology Application	Country			
		India		Ukraine	
		Free Rider Technology?	Qualitative Baseline	Free Rider Technology?	Qualitative Baseline
Supercritical Coal	All	No	Steam turbine plant with subcritical, PCF boilers	Yes	Coal-fired steam turbine plant
IGCC	All	No	Steam turbine plant with PCF boilers	No	Coal-fired steam turbine plant
NGCC	All	No	Gas-fired steam turbine plant	No	Gas-fired steam turbine plant
Wind Turbine	Off-grid	No	Diesel generators	No	Diesel generators
	On-grid	No	A composite representing average emission rate of recently-built capacity.	No	A composite representing average emission rate of all existing capacity.

Solid Oxide Fuel Cells	Commercial co-generation	No	Diesel generators	No	Diesel generators
	Low-cost fuel	No	A composite representing average emission rate of recently-built capacity.	No	A composite representing average emission rate of all existing capacity.
	Distributed generation	No	Use Project-Specific Approach	No	Use Project-specific Approach
CNG Vehicles	Passenger Cars	No	Composite of gasoline and diesel vehicles	Yes	Composite of gasoline and diesel vehicles
	Transit Busses	No	Composite of gasoline and diesel vehicles	Yes	Composite of gasoline and diesel vehicles
Hybrid (electric/gasoline) Vehicles	Passenger Cars	No	Composite of gasoline and diesel vehicles	No	Composite of gasoline and diesel vehicles
	Transit buses	No	Composite of diesel vehicles	No	Composite of diesel vehicles
Gas-to-Liquids		No		No	
Coalbed Methane Recovery	Methane	No	Benchmark Not Required	No	Benchmark Not Required
	CO2/Onsite electricity generation	No	A composite representing average emissions rate of recently-built capacity	No	A composite representing average emissions rate of recently-built capacity
	Transfer of gas to pipeline	No	Use Project-Specific Approach	No	Use Project-Specific Approach
Energy-Plex	All	No	Benchmark not Provided	No	Benchmark not Provided

Attempts were made to calculate the quantitative baselines for each of the technologies for both reports. However, quantitative baselines have not been computed for most of the technology/country combinations, because the data required to compute the baselines is not available. Quantitative baselines are, however, developed for two of the electricity generation technologies (supercritical coal and IGCC) in India. The calculated benchmark in Table 5 is the average life-of-plant heat rate for five coal-fired Indian power plants opened in the last five years.

Table 5. Baselines for Two Indian Electricity Generation Technologies

Technology	Technology Application	India	
		Qualitative Baseline	**Quantitative Baseline**
Supercritical Coal	All	Steam turbine plant with subcritical, PCF boilers	10.211 MMBtus/MWH
IGCC	All	Steam turbine plant with PCF boilers	10.211 MMBtus/MWH

The third report, *Case Study Analysis of the U.S. and EU Proposals*, provides further development of the technology matrix through case study analysis but adds an additional element of comparing the technology matrix to formal market mechanism proposal put forth by the United States and the European Union (EU). The U.S. proposal provides for a "superior performance" test evaluating projects based on their emissions performance. This test requires projects to reduce emissions beyond the average for comparable activities. The EU proposal provides a "positive list" of GHG abating technologies and processes. Only those projects using technologies appearing on the list would qualify for emission credits. Also in this report, the technology matrix is broken out into two distinct proposals, the full technology matrix and the hybrid technology matrix. The full technology matrix proposal is as described in the above sections. The hybrid technology matrix is a combination of the technology matrix free rider test and the baseline development portion of the U.S. proposal, which stipulates that credits would be awarded based on a reference scenario consisting of a set of recent and comparable activities or facilities. The purpose here is to test the efficacy of the technology matrix against the other proposals, in the context of potential real world projects, as a means of screening out free rider projects. In addition, this exercise further refined the strengths and weaknesses of the technology matrix. The results of this report's analyses are presented in Table 6.

Table 6. Case Study Results

Project Information					Case Study Result: Is the Project Correctly Identified as Additional or Free Rider?			
ID	**Country**	**Title**	**Addi-tional**	**Free Rider**	**US Approach**	**EU Positive List**	**Full Technology Matrix**	**Hybrid Technology Matrix**
Electricity Generation								
ES1	India	IGCC Power Plant	U		Yes	No	Yes	Yes
ES2	India	Heat Rate Improvement		U	Depends on X	Yes	Yes	Yes
ES3	India	Fuel Switching		U	Depends on X	Yes	Yes	Yes
ES4	India	Natural Gas Combined Cycle		U	Yes	No	No	No
ES5	India	Gas Turbine Plant	U		No	No	No	No
ES6	India	Wind Power	U		Yes	Yes	Yes	Yes
ES7	Kazakhstan	IGCC Power Plant	U		Yes	No	Yes	Yes
ES8	Tajikistan	Hydropower		U	No	Yes	Yes	Yes
ES9	India	Distributed Generation: Fuel Cells	U		Yes	No	Yes	Yes
ES10	China	Transmission Capacity Expansion		U	No	Indeter-minate	Yes	Yes
ES11	India	Carbon Sequestration Technology for an IGCC Power Plant	U		Yes	No	Yes	Yes
Industrial Sector								
IS1	Azerbaijan	Installation of District Heating System		U	Yes	Indeter-minate	Yes	Yes
IS2	Kazakhstan	Cogeneration at Food Processing Plant		U	Yes	Indeter-minate	Yes	Yes
IS3	Argentina	Variable Frequency Drives	U		Inde-terminate	Yes	No	No
IS4	Brazil	Retrofit of Energy Efficient Motors		U	No	Indeter-minate	Yes	Yes
IS5	China	Coke Oven Underfiring Rate Improvement	U		Yes	Yes	Yes	Yes
IS6	Tajikistan	PFC Reductions at Aluminum Plant	U		Yes	No	Yes	Yes
IS7	China	Coal Ash Utilization	U		Yes	Indeter-minate	No	No
IS8	Chile	Building Insulation Improvement	U		No	Indeter-minate	Inde-terminate	Inde-terminate

Project Information					Case Study Result: Is the Project Correctly Identified as Additional or Free Rider?			
ID	**Country**	**Title**	**Addi-tional**	**Free Rider**	**US Approach**	**EU Positive List**	**Full Technology Matrix**	**Hybrid Technology Matrix**
IS9	Jordan	Highly Efficient Fertilizer Complex		U	Yes	Indeter-minate	Inde-terminate	Inde-terminate
IS10	China	Industrial Boiler Shutdown		U	Inde-terminate	Yes	Yes	Yes
IS11	South Africa	Coal Mine Methane Recovery	U		Inde-terminate	Yes	No	No
IS12	Argentina	Landfill Gas Flaring		U	Inde-terminate	Indeter-minate	No	No
IS13	Kazakhstan	Recovery of Associated Natural Gas		U	Inde-terminate	Indeter-minate	Yes	Yes
Transportation								
TS1	India	Dedicated CNG Taxis	U		Yes	Yes	Yes	Yes
TS2	India	New Gasoline-Fueled Taxis		U	No	Indeter-minate	Yes	Yes
TS3	China	Aluminum Rail Cars for Efficient Coal Transport		U	Inde-terminate	No	No	No
TS4	South Africa	Clean Diesel in Transit Buses		U	No	No	No	No
TS5	Mexico	Electric Vehicles in Mexico City	U		Yes	Yes	Yes	Yes
TS6	Thailand	Smart Toll System	U		Inde-terminate	Yes	Yes	Yes
TS7	Ukraine	46 New Conventional Diesel Buses	U		Yes	Yes	No	No
TS8	India	New Two-Wheelers	U		Depends on X	Yes	Yes	Yes
TS9	Brazil	Improving Road Infrastructure	U		Inde-terminate	Yes	Indeter-minate	Indeter-minate
Land Use/Forestry								
LU1	Mexico	Forest Protection and Management	U		Yes	No	No	No
LU2	Russian Federation	Afforestation of Marginal Agricultural Land	U		No	No	Indeter-minate	Indeter-minate
Residential								
RS1	South Africa	Construction of Energy-Efficient Homes in South Africa	U		Yes	Yes	No	No
RS2	Mexico	Sale of High-Efficiency Light Bulbs for Homes		U	Inde-terminate	No	No	No
RS3	Russian Federation	Energy Efficiency of Seven Apartment Buildings	U		Yes	Yes	No	No
Commercial								
CS1	Philippines	Energy Efficiency and Conservation Measures in Commercial Buildings	U		Yes	Yes	Indeter-minate	Indeter-minate
CS2	Indonesia	Motor Replacement Project in Commercial Office Buildings in Jakarta	U		Yes	Yes	Yes	Yes

Lessons Learned

NETL's case study approach and analysis of the technology matrix reveal several key areas that require further attention. First, the process of defining the model counterfactual (i.e. the qualitative baseline) is subjective, relying on expert opinion and judgment. Given this subjectivity, it is important that counterfactuals be based on a broad consensus rather than the opinions of a few individuals. Thus, a *Delphi* approach to defining model counterfactuals is recommended for future technology matrix development. Specifically, panels of international experts should be brought together to define the model counterfactuals, based on consensus opinion. Although, using the

Delphi approach would continue to result in subjective counterfactuals, they would reflect the consensus of a wide range of expert opinion.

Second, it is clear that the data currently available is inadequate for supporting quantitative baseline development under the technology matrix. This data problem is exacerbated by an important element of technology matrix benchmarking, periodic updating of the benchmarks. As noted earlier, the data used to create benchmarks will need to be collected and updated on a periodic basis and benchmarks will need to be re-calculated (once every five-years is recommended) to ensure that the benchmarks are up to date. This will ensure that the benchmark group provides a means of quantifying what would have happened in the absence of the project, not just at project initiation, but also throughout the life of the project. This data problem is not only true for the technology matrix but all baseline development approaches. In most cases, developing countries lack the institutional capacity to support the data requirements for accurate quantitative baselines and lack funding to develop the necessary institutional capacity. To meet the data needs of the various approaches to baseline development under market-based mechanism systems, either existing data collection agencies must be upgraded, or a new institution could be established to collect and validate the needed data.

Third, as currently constructed, the market penetration test stipulates that if a given technology has been unable to gain market access in a particular country it would qualify for inclusion in the matrix. In this way, the market penetration test will always qualify first-of-its-kind projects even if the applied technology is commercially viable for the specified country. In other words, some first-of-its-kind projects may in fact be free riders, but the market penetration test would still qualify them. A correction to this potential problem may be to use a global or regional market penetration test as a means of screening out this type of first-of-its-kind projects. However, one drawback would be that the improved stringency of the technology matrix would disqualify technologies that are truly additional in some countries.

Finally, the technology matrix is set up to evaluate all of the processes included in a project at the same time. As a result, it is unequipped to deal with a project that involves the installation of an advanced technology in only one part or portion of a particular project. For the moment, the technology matrix is left with qualifying or not qualifying the entire project rather than isolating only those portion(s) of the project utilizing the advanced technology. One solution would be to account for the emission reductions from the advanced technology and qualify just that part of the project. However, procedures for undertaking such an analysis need to be specified, and guidelines for establishing the benchmark need to be developed.

Using the Technology Matrix: A Brief Summary

Once the matrix is in place for a particular country, it becomes very simple to use. Project developers first demonstrate whether or not their project(s) meets the criteria that would allow use of the modified technology matrix (Table 1). If the criteria is met, the project developers simply demonstrate utilization of a qualifying technology (ies). If the project does not involve a qualifying technology, then project developers have the opportunity use the project-specific approach. Finally, project developers would then use the pre-calculated baseline to determine their project's emission reductions.

Advantages of the Technology Matrix

The technology matrix approach offers a number of potential advantages. With its focus on qualifying technologies in advance of project development, it is designed to substantially reduce the costs of project evaluation and development to project developers. Although similar to the benchmarking approach, it has the advantage of a rigorous test for free rider projects. In addition, the focus on individual technologies rather than sectors or sub-sectors enables the tailoring of benchmarks to groups of projects characterized by similar technological characteristics. Where appropriate, separate benchmarks can even be provided for different applications of the same technology. The resulting benchmarks exhibit a high degree of specificity with respect to both the technological and market characteristics of individual projects. In effect, the technology matrix groups projects with similar technological and market characteristics within economic subsectors, enabling the development of a more accurate benchmark for each group.

A major conclusion drawn from all the case study analysis is that every baseline methodology should employ a back-up methodology to capture those projects that either do not apply or are misclassified by the main methodology. The technology matrix already is set up to employ the project-specific approach as its back-up methodology. Use of the project-specific approach in this way ensures that the technology matrix will not in and of itself eliminate any projects (e.g. projects using commercial technologies) from participation in market mechanisms and it ensure maximum participation in the market mechanisms. Furthermore, projects that must qualify under the project-specific approach may still use the benchmarks from the technology matrix for determining emission credits; thus reaping at least a portion of the cost benefits offered by the matrix.

Analysis from the third report demonstrated that the technology matrix was the most successful at identifying free rider projects. In total 22 out of 40 projects were correctly identified as either additional or free riders. Moreover, only five free rider projects were incorrectly identified as additional under the technology matrix. Thus, based on the results of the hypothetical case studies, it appears that the technology matrix provides a more stringent and conservative free rider test, which may, in the long run, lead to a lower level of error in the allocation of emission credits. In essence, the technology matrix is more successful because it analyzes the project technology itself based on market penetration and economic feasibility. These criteria directly address the issue underlying free ridership; that is, would the project be undertaken absent the incentives provided by market mechanisms.

In addition, the less extensive data requirements of the technology matrix indicates that this approach will be less costly to implement than other approaches, particularly in terms of collecting and preparing data for project evaluation. For example, the U.S. proposal is data intensive relying heavily on sector-wide data to undertake both the free rider test and benchmark development. Thus, if the data is unavailable or completely non-existent, it will be impossible to evaluate projects using the U.S. proposal. In this situation, transaction costs could increase dramatically as the institutional capacity to collect this data would need to be developed prior to implementing market-based mechanisms. In contrast, the technology matrix is much less dependent on data availability for qualifying technologies, thereby lowering the financial requirements for implementing market-based mechanisms.

In summary, the technology matrix offers the best opportunity for project developers and architects of market-based mechanisms to achieve the objectives of transparency, accuracy and minimization of transaction costs. The technology matrix approach to baseline development is easily replicable from one country to the next and once a country-specific matrix has been established, it is easy to use. Project developers merely need to demonstrate use of a pre-qualified technology and then use the pre-established benchmark to calculate emission credits. This approach has proven to be highly accurate in classifying additional and free rider projects through the use of a rigorous free rider test and requires updating of benchmarks over time so that they remain relevant to ongoing and future projects. Finally, transaction costs are minimized by shifting baseline development costs away from project developers to institutional development of individual matrixes yet maximum participation in the mechanisms is ensured by the use of a back-up methodology.